FAST ORBIT FEEDBACK AT PLS-II STORAGE RING

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Abstract

The transverse position of the electron beam in the Pohang Light Source-II is stabilized by the global orbit feedback system. A slow orbit feedback system has been operating at 2 Hz, and a fast orbit feedback (FOFB) system at 1 kHz was installed recently. This FOFB system is consists of 96 electron beam position monitors, 48 horizontal fast correctors, 48 vertical fast correctors and VME control system. We present the design and implementation of the FOFB system and its test result. Analysis through the simulation is presented and future improvement is discussed.

INTRODUCTION

After the completion of the PLS-II project to upgrade PLS on March 21, 2012, Pohang Light Source II (PLS-II) [1] is now in full operation. PLS-II has 20 insertion devices (IDs) which change gap frequently during operation. It causes a beam orbit disturbance which slowly cured by a slow orbit feedback (SOFB) at PLS-II [2] operates with 2 Hz. Also, fast acquisition data of the electron beam position monitors (BPMs) have shown that there is orbit perturbations lie in a frequency range around 30 Hz and 60 Hz. Electron beam orbit stability is crucial requirement of the PLS-II to suppress the photon beam fluctuations at the experimental stations. Therefore, a fast orbit feedback (FOFB) system has been required to maintain the orbit stability in the DC to 100 Hz bandwidth. In 2010, we planned and designed PLS-II lattice which enable the implementation of the fast orbit feedback system. Requirements are 8 BPMs per cell whose sampling rate is 4 kHz and 2 sets of the fast correctors per cell placed the both side of the insertion devices. The rise time of the fast correctors is should be below 1 ms. We confirmed that the fast correctors are controlled at 1 kHz rate and established the calculation and network system with VME and RFM.

This paper will present the system configuration and the performance of the FOFB system at PLS-II which was installed at 2015 and is operating successfully. Additionally, we presents the diagnosis and outlook of the FOFB at PLS-II through the simulation study.

SYSTEM CONFIGURATION

The FOFB system at PLS-II consist of the 96 electron BPMs (Libera Brilliance [3]), 48 fast correctors in each plane, 13 VMEs where one for master and 12 for each cell, radio frequency module (RFM) for network, and a timing trigger. Figure 1 describes system configuration of the FOFB at PLS-II. Fast acquisition of the BPMs are used for FOFB with grouping for synchronization. We installed 48 fast correctors around stainless steel BPM bellows, at the ends of the 24 straight sections. The fast correctors is designed to kicks beam in the ±20 μrad range. Matrix calculation is done by the VME at the FOFB rate and the RFM convey data cell to cell. Table 1 summarize the components FOFB system.

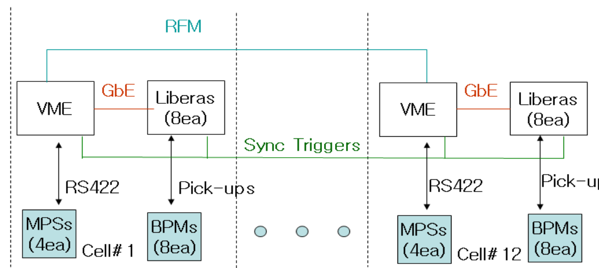

Figure 1: Configuration of the FOFB system at PLS-II.

We adopted hybrid method which combine the SOFB and the FOFB. The SOFB and the FOFB operate separately and communicate with each other simultaneously. The SOFB at PLS-II consists of 96 BPMs and 96 slow correctors which controlled at 2 Hz. The FOFB consists of 96 BPMs and 48 fast correctors which operates at 813 Hz. The FOFB and SOFB share the BPMs and the slow correctors downloads the orbit made by the fast correctors at 2 Hz to relieve the value and prevent the saturation of the fast correctors.

We constructed the timing chart of the one cycle of the FOFB procedure. It consists of BPM data communication, VME matrix calculation, and the fast corrector setting. We measured the duration of the each procedure and minimize it to establish 1 kHz repetition rate of the FOFB system. Currently, the FOFB at PLS-II is running at 813 Hz because of the system stability issue (see Fig. 2).

Table 1: FOFB System Components

Parameters	Value
Number of digital BPM (Libera)	96
Number of corrector(H/V)	48 each
Number of VME	12 (node) + 1 (master)
Fast data sharing between VMEs	RFM network

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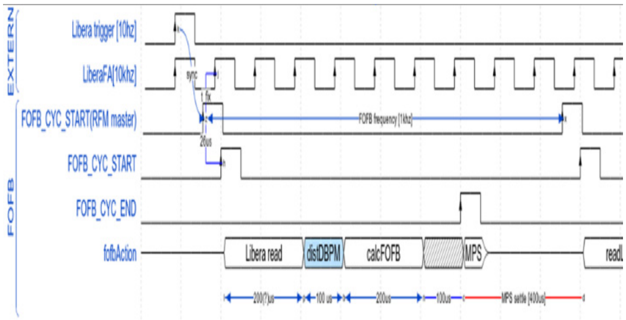

Figure 2: 1 kHz FOFB timing chart.

FOFB PERFORMANCE

As a third generation light source, the synchrotron PLS-II has 20 IDs. Each ID controls the photon property by changing the magnet gap. During the magnet gap change, electron beam are kicked at the ends of the ID because of the imperfection of the magnet design and it changes electron orbit in the storage ring. Therefore we need to counteract the ID gap change effect and make the gap change as transparent to the other beamline. However, the SOFB operate at 2 Hz and it takes several seconds to recover the ID gap change effect. The FOFB operates at 813 Hz effectively mitigate the ID effect and we summarize the result at Fig. 3. At Fig. 3, we measured RMS orbit error along time while changing ID gaps one by one. When the FOFB was not working, RMS orbit error increases up to 15 µm and the error decrease slowly by the SOFB. When the FOFB is working, the RMS error increase up to 0.2 µm.

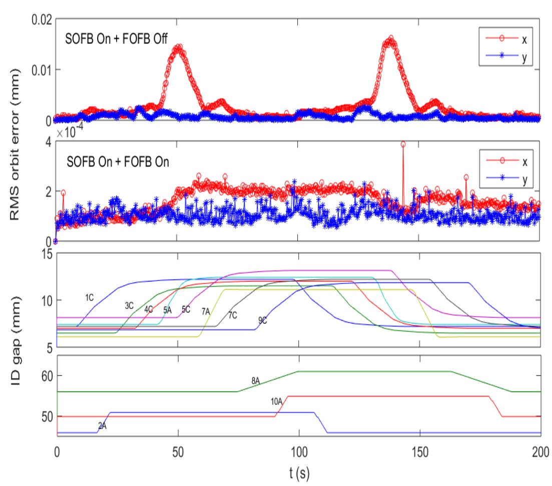

Figure 3: ID effect compensation.

The other role of the FOFB is the decrease of the the beam perturbation from DC to 100 Hz. We compared the Fourier transform of the BPM 10 kHz data when whether the FOFB is working or not. Upper of the Fig. 4 presents the horizontal and vertical BPM 1-1 FFT data comparison from DC to 200 Hz respectively. Lower part of the Fig. 4 shows the integrated power spectrum of the BPM noise from DC to 200 Hz. Different BPM shows slightly different result but overall result state that the 813 Hz FOFB suppress the orbit perturbation below 60 Hz effectively, but it could not cover the perturbation faster than 60 Hz. Horizontal orbit error is manly 30 Hz so the FOFB suppress it well, but the FOFB cannot suppress the 60 Hz vertical perturbation.

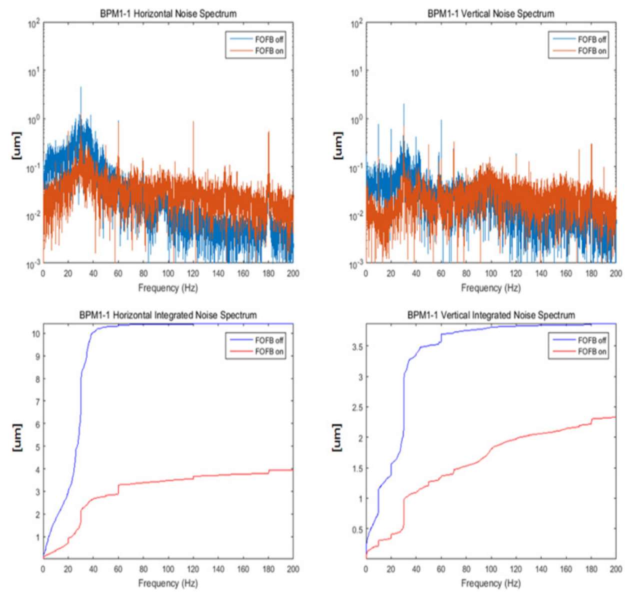

Figure 4: BPM 1-1 noise spectrum and its integrated power spectrum distribution graph. Noise under 60 Hz suppressed well by the FOFB.

We simulate the FOFB performance using the BPM 10 kHz data and the response matrix of the fast corrector sets to confirm the FOFB performance normalcy and to plan the future upgrade of the FOFB system. Figure 5 describes the calculated RMS orbit error along the FOFB frequency using the simulation. As the speed of the FOFB increases, horizontal orbit error which is from the mainly 30 Hz perturbation is suppressed earlier than the vertical orbit error. The vertical orbit error which has 60 Hz main perturbation is effectively suppressed when the FOFB is over 2 kHz.

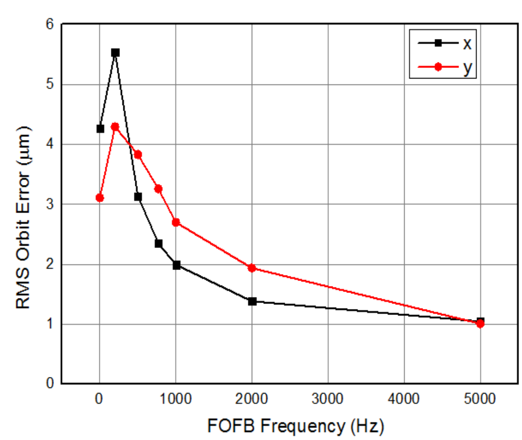

Figure 5: Calculated RMS orbit error along the rate of the FOFB.

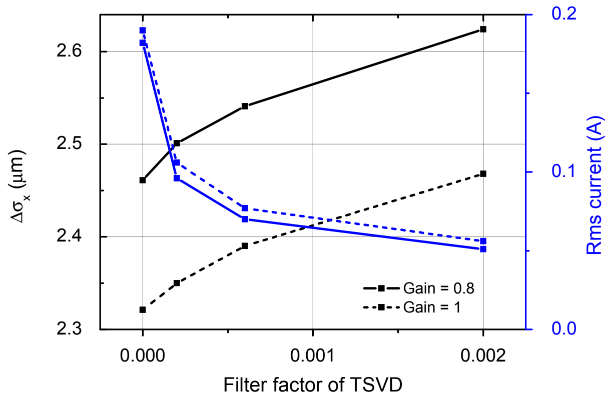

Figure 6: Layout of papers.

As described before, the fast corrector value is relieved at the SOFB rate by the download process to increases the stability of the FOFB system by maintaining the current of the fast corrector possibly low. Additionally, we introduced the truncated singular value decomposition (TSVD) technique for the FOFB stability. TSVD using the truncated singular value σ such as

$$\sigma_{truncated} = \frac{\sigma^2+\alpha}{\sigma}, \tag{1}$$

where the α is the filter factor. Figure 6 describes the RMS orbit error and the RMS current of the fast correctors along the filter factor of TSVD. When we use normal SVD algorithm (filter factor is zero), corrector current is hard to decrease but the orbit error is easily increases by the correction gain change. The TSVD, however, decreases the corrector current significantly while the RMS orbit expense is small. We implemented the TSVD algorithm in the FOFB system and experienced the improvement during the user operation in March 2016.

CONCLUSION

A fast global orbit feedback was designed and successfully operated at the synchrotron PLS-II, where it corrects the orbit at a rate of 813 Hz. A global fast orbit feedback in the PLS-II storage ring is consist of 13 VME boards, 96 BPMs, 48 vertical and 48 horizontal correctors. The reduced latency should allow the damping of orbit perturbations significantly below 100 Hz, especially when dedicated corrector magnets are used. The feedback can damp orbit perturbations of 30 Hz in the horizontal plane. Vertically, the FOFB need to be faster for the correction of 60 Hz perturbations. User operation with a fast feedback at the storage ring beamline have already been performed successfully.

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